

APPENDIX L

WATER YIELD ANALYSIS

Prepared by Lolo National Forest

Methods

Methods for determining the effects of vegetation removal on water yield have been developed for the Lolo National Forest (Pfankuch, 1973), and reviewed and refined for US Forest Service Region One (USDA Forest Service, 1978). The methods were developed for areas with snowmelt-dominated runoff. Equivalent clear-cut area (ECA) analysis is a key component of these methods. The basis of the ECA analysis is that water yield increases when vegetation is removed, whether by natural disturbance such as fire, or by human disturbance. When all of the vegetation from a land unit is removed (100% crown removal), the equivalent clear-cut area is also 100%, in the first year. ECA is not directly related to the proportion of vegetation removed from a land unit, however. For example, if 50% of the crown is removed, the ECA is 40% in the first year. For, crown removal up to 15%, ECA is 0%; for crown removal of 90%, ECA is 95% in the first year.

Water yield increase is greatest immediately following vegetation removal. In years subsequent to vegetation removal, the ECA (and water yield increase) declines, or “recovers”, because of vegetation re-growth. The rate of re-growth and thus ECA recovery is based on evapotranspiration, snowfall accumulation related to patch dynamics, and the relationship between water yield and changes in vegetation interception. This re-growth relationship is expressed as a recovery curve.

Water yield increase over time can be calculated for each land unit. Land unit size (acres) is multiplied by the amount of crown removed (%) to get the initial acres of equivalent clear-cut area. The year of treatment is subtracted from the analysis year to get the time since treatment. Based on the time since treatment, the recovery curve gives the associated percent recovery value. The initial ECA minus the recovery ECA produces the residual or effective ECA in acres for the analysis year. Runoff depth (feet) for the land unit is determined, usually from isoclines of runoff based on precipitation. Runoff depth is multiplied by the effective ECA to get the runoff volume for the unit in acre-feet. The runoff volume is multiplied by a runoff increase factor to get the residual water yield increase for the unit (the runoff increase factor expresses the proportion of runoff increase expected from vegetation removal at a given elevation). Residual water yield increase is then compared to the average annual water yield for the area of interest to determine the relative magnitude of the residual water yield increase, or percent water yield increase.

Results

Equivalent clear-cut area analysis was used to model residual water yield increases in the St. Regis watershed from documented harvest history on National Forest land, and for 1910 fire history data. The Timber Stand Management Recording System (TSMRS) database for the Lolo

National Forest was queried to obtain all records of documented timber harvest. USGS HUC 6 watersheds were used to delineate the tributary watersheds. Note that unlike the other watersheds, “Lower St. Regis” HUC 6 is a complex of drainages that are tributary to the St. Regis River, rather than tributary to a single stream that is tributary to the St. Regis River. For this reason, the results of the analysis for the Lower St. Regis cannot be evenly compared to the other HUC 6 watersheds. Thus, the results for the complete watershed, identified by the St. Regis HUC5, would be more appropriate for evaluating increased water yield on the lower reaches of the St. Regis River.

Timber Harvest on National Forest Land

Documented timber harvest on the National Forest in the St. Regis watershed began in the 1960s. Harvest activity increased in the 1970s, and peaked in the 1980s and early 1990s, and has diminished in the past decade. Harvest before the 1960s is assumed to be limited because of relatively low demand and lack of equipment necessary to harvest on large scales. Undocumented harvest activity prior to the 1960s is unknown, but is assumed to have a negligible effect on water yield increase.

According to ECA analysis results, residual runoff increase for the St. Regis River in 2003 was 11,841 acre-feet (**Table L-1**). Mean annual water yield for the St. Regis River based on USGS data collected at the gaging station in St. Regis, is approximately 430,000 ac-ft/year. ECA-modeled water yield for the St. Regis River is 2.8% greater than the average annual mean water yield due to past harvest activity on National Forest land.

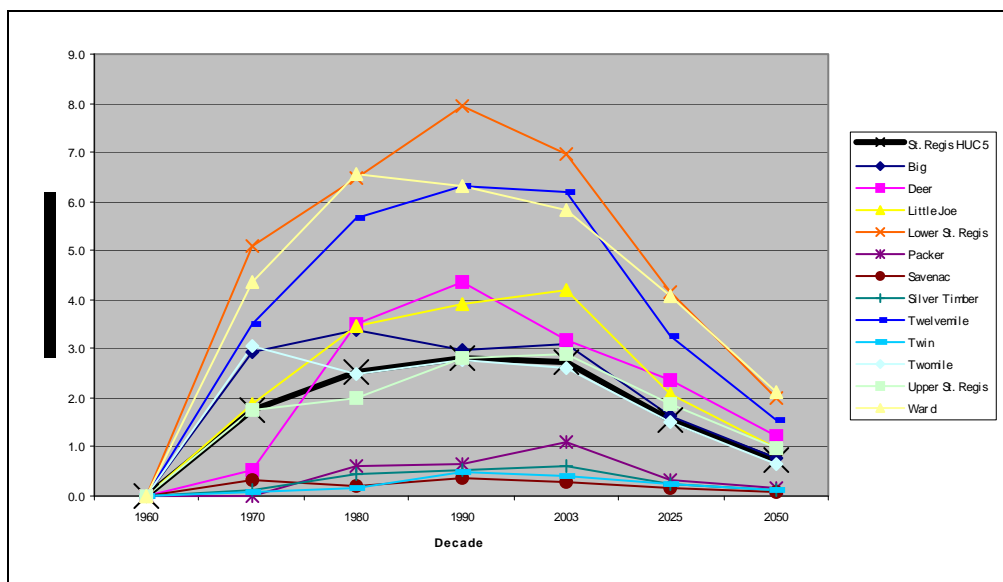
Flow data for the tributary watersheds is very limited. To obtain a water yield value for the tributary watersheds, mean annual water yield for the St. Regis River was distributed among the tributaries on an area-weighted basis. The area-weighted proportions of the St. Regis River mean annual runoff for each tributary watershed was used to calculate the percent water yield increase for each tributary (**Table L-1, Figure L-1**).

Table L-1. Residual runoff (RO) and water yield increase to the St. Regis River from timber harvest on National Forest land, analysis year 2003

Tributary	Effective ECA (ac)	Percent of HUC6	Runoff Depth (ft)	Runoff Volume (ac-ft)	Average Elevation (ft)	Runoff Increase Factor	Runoff Increase (ac-ft)	Mean Annual Runoff (ac-ft/year)	Percent Water Yield Increase
Big	1858	7.6	2.1	17	4708	0.405	1568	50855	3.1
Deer	783	7.2	2.1	15	4951	0.390	637	20106	3.2
Little Joe	2263	8.2	2.1	17	4833	0.400	1886	44942	4.2
Lower St. Regis	1759	7.2	1.9	13	3959	0.440	1483	21288	7.0
Packer	340	3.0	1.9	6	4644	0.400	261	23654	1.1
Savenac	167	1.5	1.2	2	4559	0.420	82	27202	0.3
Silver Timber	549	2.9	1.8	6	4310	0.430	433	70961	0.6
Twelvemile	2721	7.1	1.9	13	4466	0.420	2191	35480	6.2
Twin	301	2.4	1.5	3	4168	0.435	197	48490	0.4
Twomile	1376	12.6	2.1	27	4604	0.410	1175	44942	2.6
Upper St. Regis	579	2.2	2.5	5	4802	0.400	579	20106	2.9
Ward	1402	9.5	2.1	21	4799	0.400	1168	20106	5.8

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St. Regis HUC5	14097	6.1	2.0	28194	4567	0.420	11841	429312	2.8

**Figure L-1. Water yield increase from timber harvest on National Forest land. Note that unlike the other watersheds, “Lower St. Regis” is a complex of drainages that are tributary to the St. Regis River, rather than tributary to a creek that is tributary to the St. Regis River****Road Template**

Additional water yield calculations were made to account for water yield increase from the permanent removal of vegetation within the corridor of the road system, the template or “footprint” of the road network. Road width varies, as does width and presence or absence of ditches on one or both sides of road segments. Cut and fill slope area also varies, resulting in changes in clear-cut area along a road corridor. The clear-cut area associated with the road network also changes overtime, primarily increasing as new roads are constructed. Residual clear-cut area also decreases as revegetation occurs on cut and fill slopes and infrequently used or closed roads.

None of the above identified road variables were considered. Instead, ECA and resulting water yield increase from removal of vegetation along the road network was determined assuming 100% residual clear cut area for the year 2003, and average road width of 35 feet (road tread, ditches, cut and fill slopes) for all roads. This resulted in conservatively high water yield calculations.

1910 Fires

The effects of the 1910 fires on water yield were also examined. Fire perimeter data for historic fires on the Lolo National Forest have been interpreted from aerial photos and vegetation mapping. A GIS layer of these fire perimeter data was used to determine the spatial extent of the 1910 fires in the St. Regis watershed (**Figure L-2**). Forty three percent (just less than 100,000 acres) of the St. Regis watershed burned in the 1910 fires (**Table L-2 and Table L-3**). The 1910 fires in this region were primarily high severity, stand replacing fires. For the purpose of this study, we assumed that 90% of the vegetation in the burned area was completely consumed. Ninety percent crown removal is equal to clear cutting 96% of the area. The ECA for the 1910 burned area is then 96% of the 43%, or about 95,000 acres. As of 2003 most (97%) of the area burned by the 1910 fires has recovered.

Table L-2. Water yield increase from the clear-cut corridor associated with the road network. Assumes 35-foot road width for all roads and 100% residual clear-cut area for model year 2003

Tributary	Effective ECA (acres)	Percent of HUC 6	Runoff Depth (ft)	Runoff Volume (acre feet)	Average Elevation (feet)	Runoff increase factor	Runoff Increase (acre feet)	Mean Annual Runoff (ac-ft/year)	Percent Water Yield Increase
Big	402	1.7	2.1	844	4708	0.405	342	50855	0.7
Deer	156	1.4	2.1	327	4951	0.390	128	20106	0.6
Little Joe	460	1.7	2.1	967	4833	0.400	387	44942	0.9
Lower St. Regis	585	2.4	1.9	1112	3959	0.440	489	21288	2.3
Packer	131	1.1	1.9	249	4644	0.400	100	23654	0.4
Savenac	77	0.7	1.2	93	4559	0.420	39	27202	0.1
Silver Timber	324	1.7	1.8	582	4310	0.430	250	70961	0.4
Twelvemile	863	2.2	1.9	1639	4466	0.420	688	35480	1.9
Twin	246	1.9	1.5	369	4168	0.435	161	48490	0.3
Twomile	285	2.6	2.1	598	4604	0.410	245	44942	0.5
Upper St. Regis	493	1.9	2.5	1233	4802	0.400	493	20106	2.5
Ward	348	2.4	2.1	731	4799	0.400	293	20106	1.5
St. Regis River	4370	1.9			4567	0.420	3614	429312	0.8

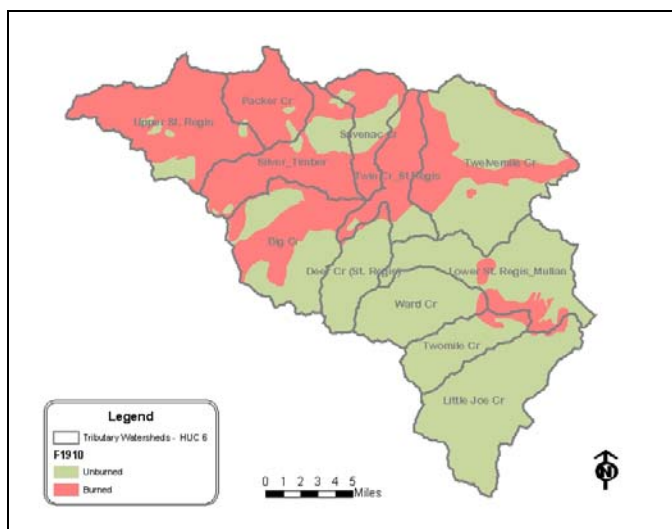


Figure L-2. Mapped extent of the 1910 fires in the St. Regis watershed

Table L-3. Fire history (1910) statistics for the St. Regis watershed

	Acres Burned (1910)	Percent Area Burned
Upper St. Regis	23869	90
Packer Creek	11188	96
Silver Timber	15603	80
Big Creek	11955	49
Savenac Creek	7334	69
Deer Creek	573	5
Twin Creek	9835	77
Twelvemile Creek	12515	33
Ward Creek	415	3
Twomile Creek	1108	10
Little Joe Creek	454	2
Lower St. Regis Mullan	3889	16
St. Regis HUC 5	98739	43

Other fires have occurred in the St. Regis watershed during the 20th century (**Figure L-3**). The next largest fire year occurred in 1919, burning primarily in Big Creek and Lower St. Regis-Mullan. Another large fire burned in Big Creek in 1924. Recurring fires would “re-set” the vegetation recovery and cause an increase in water yield. The magnitude of the increase would depend on the vegetation removed (re-growth from the previous fire) and the intensity and severity of the fire (how much crown is removed). The effects of these fires on water yield were not analyzed.

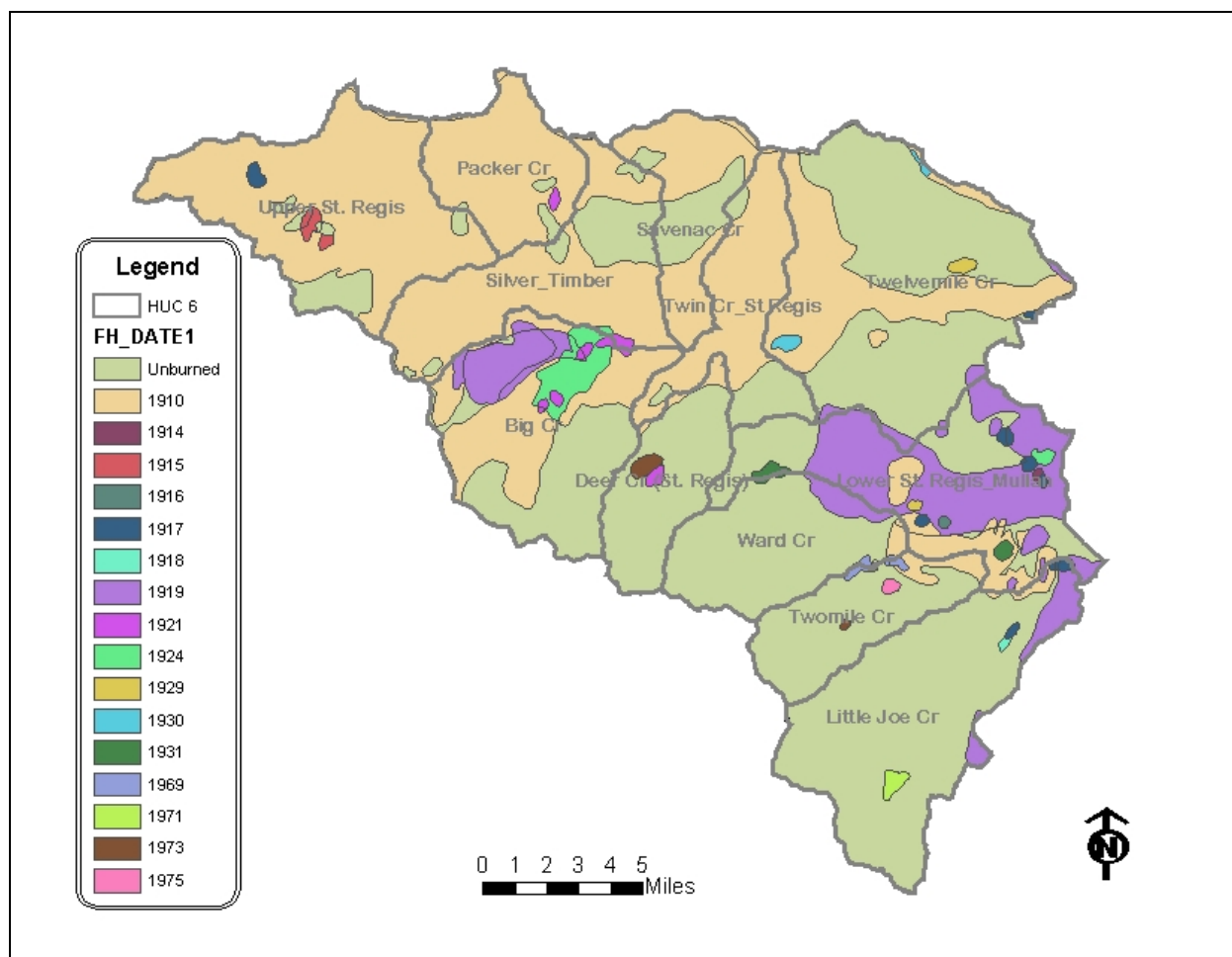


Figure L-3. Twentieth-century fires in the St. Regis watershed. Not all-inclusive.

Discussion

Pfankuch (1973) established the general rule that streams on the Lolo National Forest can, on average, sustain a 10% increase in water yield, in part due to the potential impacts from increased peak flows associated with increased water yields. Pfankuch's water yield increase limit for highly erosive drainages and streams in poor condition is less (~8%) and for drainages with stable soils and geology, and excellent stream conditions, the water yield limit is greater (~10-15%).

Assuming that the St. Regis River and its tributaries in 1910 were not in excellent condition because of the impacts from frontier development including railroad construction, but were also not in poor condition based on the level of development relative to current development. Water yield increase from the fires exceeded the 10% threshold for all tributaries, except for Deer, Ward, Twomile, and Little Joe (**Figure L-4**). For the entire St. Regis River water yield increased by 18.5% immediately after the fires. Not until the 1920's did water yield increase from the fires drop below the 10% increase threshold for the whole St. Regis watershed.

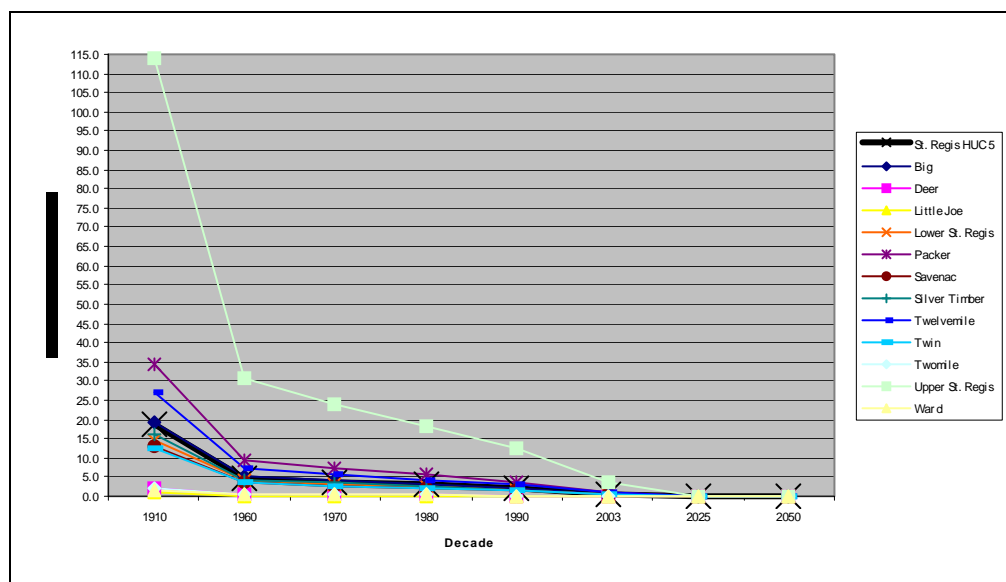


Figure L-4. Water yield increase from 1910 fires

If it were assumed that stream conditions in 1910 were excellent, the water yield effects of the fires in Packer, Twelvemile, Silver-Timber, and Big Creek exceeded the 15% threshold, and exceeded 12% in Lower St. Regis, Savenac, and Twin.

The impacts of vegetation loss on water yield due to the 1910 fires in many of the tributary drainages to the St. Regis River had the potential for tremendous geomorphic effects, more so than the water yield impacts from timber harvest history on the National Forest. Water yield increase from timber harvest on National Forest land has approached the poor stream condition threshold (8%) in one tributary. Lower St. Regis had just less than 8% water yield increase, which peaked in the 1990s. Ward Creek in the 1980s peaked at 6.5% increase and Twelvemile peaked in the 1990s at 6.25% increase. All other tributaries have had water yield increase peaks less than 5% from timber harvest on the National Forest.

Combining effects of documented timber harvest and the 1910 fires, four tributary watersheds had greater than 8-10% water yield increases: Upper St. Regis, Packer, Twelvemile, and Lower St. Regis (**Figure L-5**). Big Creek and Little Joe rose above 5%, Big in the 1970s and Little Joe in the 1980s. All other tributary watersheds remained below 5% water yield increase from the combined impacts of harvest and fire, including the whole St. Regis River. Water yield increase from clear cutting of the road corridor is greater for watersheds with more roads, but small for all watersheds when compared to the effect of harvested stands or burned areas.

Other activities affecting water yield were not analyzed. Clearing for residential subdivision and business development are other likely contributors to increased water yield.

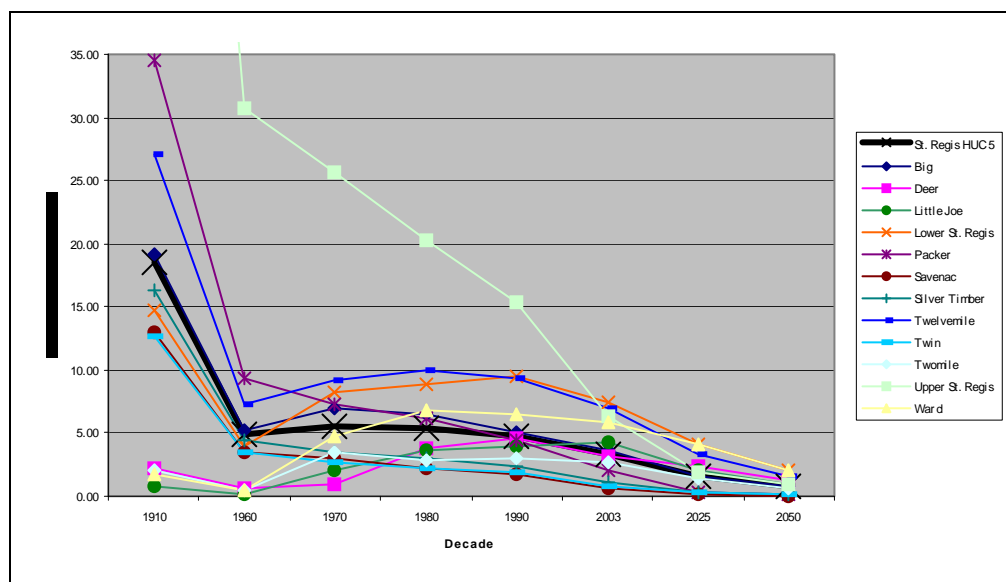


Figure L-5. Combined water yield increase from timber harvest and 1910 fires.

Based on this analysis of water yield increases, the effects of National Forest timber harvest activity alone have not likely been detrimental to the St. Regis River or its tributary streams. Stream impacts from water yield increases were likely the result of the 1910 fires. Water yield increases from the 1910 fires in combination with water yield increased due to National Forest harvest activity are not significantly greater than the effects of either activity (harvest or fire) alone because of the temporal disparity of the two activities.

High severity fires such as the 1910 fires in the St. Regis watershed are not unusual or unnatural. Still, streams within heavily burned drainages recover over time; otherwise watershed effects due to a large fire at some period in history would permanently impact most streams. However, the effects of the 1910 and other fires on channel morphology may persist today, in part due to activities that have further reduced and in many cases continue to reduce the stability of vulnerable stream channels attempting to recover from fire-induced water yield impacts. These activities include road encroachment, alteration by development of transportation corridors, and other activities such as timber harvest, particularly timber harvest or other clearing within riparian areas.

Water yield increase values provided in this report are modeled approximations for the increase in runoff volume from vegetation removal. These values do not account for the effect the road system has on routing water and changes to the hydrograph. We do not currently have a way to model these latter effects, although research has shown that such effects are real (Wemple and Jones 2003).

Literature Cited

Pfankuch, D. 1973. Vegetation manipulation guidelines for the Lolo National Forest; a revision and updating of the October 1967 procedures. USDA Forest Service. Lolo National Forest. April, 1973. 69 p.

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Wemple, B.C. and J.A. Jones. 2003. Runoff production on forest roads in a steep, mountain catchment. Water Resources Research 39(8), 1220, doi:10.1029/2002WR001744, 2003.